We thank the reviewer# 1 for the review and the comments. All comments (in italics) are addressed below (in bold).

General comments

Snow cover has a strong influence on surface energy balance but does not always uniformly blanket the ground. There have therefore been many papers proposing parameterizations for fractional snow-covered area in surface energy balance models, often very simple and based on limited observations. Ideally, a seasonal snow cover parameterization will account for terrain influences, the scale of the model cells and hysteresis between accumulating and melting snow covers. Helbig et al. build on their valuable earlier work to present such a parameterization and evaluate it with several extensive observed datasets. There is good work here, but it is very hard work for the reader; I have read the paper three times and am still struggling. I think that the descriptions, the evaluations and the algorithm itself need to be substantially simplified.

Thank you very much for this comment. We went over the manuscript to make it easier to read and have rewritten large parts. In particular, we completely rewrote the description of the algorithm, and now also included two figures to better illustrate how it works. Please see our answers on all issues below.

We are referred to Helbig et al. (2015b, 2020) for details of the algorithm, and it is actually impossible to tell what is being done here without reading those papers. Brief explanations of how c, d, μ *and* ξ *are calculated should be given. The appendix will be essential (but not quite sufficient) for anyone wishing to implement this algorithm in another model, and the schematic in Figure 1 should be moved to that appendix (the figure is not fully comprehensible just from material presented in the main text). For readers wanting to get an overview of the method, I suggest that an alternative Figure 1 showing typical modelled* $fSCA$ *behaviour over a season would be better (this is more or less done in Figure 7, but without explaining why the models differ in the ways that they do).*

We completely rewrote the description of the $fSCA$ **algorithm and also added two new figures to illustrate and better understand our algorithm. Furthermore, we published the algorithm code on a gitlab repository and linked it to EnviDat, an environmental data portal.**

Six different performance measures are presented with very little consideration of what aspects of performance they measure and a lack of context for what could be considered a good performance. The Kolmogorov-Smirnov test statistic implies a significance test and the Q-Q plot statistic suggests a comparison of distribution shapes that are never presented. Cut this down to a set of measures that are meaningfully used to measure performance and *to communicate information.*

We reduced the number of measures to NRMSE, RMSE and MPE, which we discuss in the manuscript.

The Niu and Yang (2007) $fSCA$ parameterization can be implemented in one line of code and includes hysteresis to some extent through snow density. Just the pseudocode for the algorithm presented here requires 32 non-comment lines and contains many apparently ad hoc design decisions: what is the significance of 14 days for new snow accumulation?how flat does a flat cell have to be? why use the flat parameterization for new snow in mountains rather than any other value? Considering uncertainties in observations revealed when different datasets overlap, errors in the modelled mass balance and ad hoc decisions, is the complexity justified? Tables 3 and 4 and Figure 7 are not very convincing in this regard.

Indeed, the closed-form $fSCA$ parameterization from Niu and Yang (2007) is a one line code - which is much simpler compared to our seasonal algorithm. However, Niu and Yang (2007) was developed and tested on monthly $fSCA$ data on spatial scales of 1° by 1°. Swenson and Lawrence (2012) demonstrated that this algorithm cannot be applied to model $fSCA$ at a daily temporal resolution. At a daily temporal resolution, the observed relationship between snow depth and $fSCA$ deviated from what Niu and Yang (2007) obtained for monthly $fSCA$. Mountainous terrain is not accounted for in the closed-form of Niu and Yang (2007). While the algorithm of Swenson and Lawrence (2012) empirically considers topography during ablation, their algorithm was, similar to that of Niu and Yang (2007), derived by linking satellite-retrieved $fSCA$ to snow data.

In contrast to Niu and Yang (2007); Swenson and Lawrence (2012) our $fSCA$ algorithm is developed for mountainous terrain using spatially measured snow depths at very high resolutions of a few meters. In order to describe realistic $fSCA$ following new snow and melt events throughout the season, we further track snow information with time at a high temporal resolution. We run the algorithm on hourly snow data, thus a much higher temporal resolution than for Niu and Yang (2007).

To perform a model intercomparison, we implemented the two closed-form parameterizations from Swenson and Lawrence (2012) as benchmark $fSCA$ model, as described in the technical description of the Community Land Surface model (CLM, version 5) (Lawrence et al., 2018). An evaluation of modelled $fSCA$ with our daily data sets showed that our $fSCA$ algorithm captures the seasonal evolution better than the CLM5.0 algorithm (cf. Table 3, 4, 5 and Figure 4, 5, 8 and 9).

It is true, that we apply some ad-hoc decisions for the seasonal algorithm, such as the 14 days time window for the detection of new snow amounts. We now provide more explanations for those decisions in Section 2 (description

of the $fSCA$ algorithm). We also mention our reasoning to apply the σ_{HS} parameterization of Egli and Jonas (2009) for new snow events in mountainous terrain, though it was derived on snow depth values from spatially distributed flat field sites in mountainous terrain. While this approximation requires further investigation, coarse grid cells with a subgrid mean slope angle of zero are rare. For Switzerland we obtain a percentage of 0.01 %. Therefore, we could not reliably evaluate the performance of our algorithm for a flat grid cell. We suggest to use $\sigma_{HS}^{\mathbf{Egli}}$ instead of $\sigma_{HS}^{\mathbf{Helbig}}$ for a completely flat grid cell to avoid $fSCA = 1$ for a subgrid mean slope angle of zero (cf. Eq. (5)). However, for a global application of our algorithm any closed-form $fSCA$ parameterization could be applied for flat grid cells. We now mention that in the discussion.

There are indeed uncertainties involved when evaluating the seasonal $fSCA$ algorithm. For the evaluation, the algorithm was implemented in a comprehensive multilayer energy balance snow cover model which we ran with analysis data from an atmospheric model. This introduces model uncertainties to the algorithm performance (ranging from model input variables to uncertainties of other model equations). Additionally, the measurement data originate from various platforms adding observation uncertainties. Therefore, in order to focus on the performance evaluation of our $fSCA$ algorithm, we ideally have to minimize seasonal snow cover model or measurement uncertainties. As was already discussed in Section 5.2.3 removing grid cells with $HS < 5$ cm improved the performance statistics considerably. We now removed modelled HS lower than 5 cm during pre-processing of the model data (Section 3.1). This reduced the scatter in Figure 8a (cf. new Figure 9a in the manuscript) and improved overall performance measures (Table 4,5).

Overall, we present an evaluation of a seasonal $fSCA$ implementation with independent high-resolution spatial as well as temporal snow depth data and snow products, something that has never been done for a seasonal $fSCA$ algorithm with such detail.

References

L. Egli and T. Jonas. Hysteretic dynamics of seasonal snow depth distribution in the Swiss Alps. *Geophys. Res. Lett.*, 36(L02501), 2009.

D. Lawrence, R. Fisher, C. Koven, K. Oleson, S. Swenson, and M. Vertenstein. Technical Description of version 5.0 of the Community Land Model (CLM), 2018. URL `https://www.cesm.ucar.edu/models/cesm2/land/CLM50_Tech_Note.pdf`. [Online; accessed 31-March-2018].

G. Y. Niu and Z. L. Yang. An observation-based formulation of snow cover fraction and its evaluation over large North American river basins. *J. Geophys. Res.*, 112(D21), 2007. doi: 10.1029/2007JD008674.

S. C. Swenson and D. M. Lawrence. A new fractional snow-covered area parameterization for the community land model and its effect on the surface energy balance. *Journal of Geophysical Research: Atmospheres*, 117(D21), 2012. doi: 10.1029/2012JD018178.